IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

Applicant:	Yan Borodovsky	Art Unit:	1756
Serial No.:	10/693,373	Examiner:	Daborah Chacko Davis
Filed:	October 24, 2003	Assignee:	Intel Corporation
Title:	COMPOSITE OPTICAL LITHOGRAPHY METHOD FOR PATTERNING LINES OF UNEQUAL WIDTH		

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REPLY BRIEF

Pursuant to 37 C.F.R. § 41.41, Applicants file this Reply Brief in response to many of the new points of argument in the Examiner's Answer mailed September 7, 2007.

At page 6, line 7-13, the Examiner's Answer contends that Applicant is incorrect in describing that Canon's multiplex exposure amounts are achieved when "three or more exposure levels" are used. In support of this contention, the Examiner's Answer points to Canon's use of "only two exposure processes."

Applicant respectfully disagrees. An "exposure process" is not an "exposure level." According to Canon:

> "the word 'multiplex' referred to above in relation to the phrase 'multiplex exposure amount distribution' means that, unlike binary exposure amount (two levels including zero level exposure amount) to be applied to a photosensitive substrate, more than binary exposure amount (three or more levels including zero level exposure amount) is given. Further, the words 'ordinary exposure (process)' are used to refer to an exposure process which is to be done with a resolution lower than that attainable with dual-beam interference exposure and to be done with a pattern different from that used in the dual-beam interference exposure." *See Canon*, para. [0032].

Canon himself thus acknowledges that a single (binary) exposure process results in two exposure levels.

Further, please note that this fundamental misunderstanding is relevant to the rejections. As discussed previously, in Canon, the *accumulation of successive dosages* is required to create a printable feature. The exposure of a previously unexposed line using a single second exposure process will be ineffective to create a printable feature since the accumulated dosage in that previously unexposed line will necessarily remain below Canon's threshold.

At page 6, line 13-15, the Examiner's Answer contends that Canon "teaches forming a pattern with only two exposure processes, and does not require a multiple exposure process in all the different embodiments."

Applicant respectfully disagrees. "Two exposure processes" are "multiple."

At page 6, line 15-page 7, line 2, the Examiner's Answer contends that some features in Canon have "a width that is less than the width of the non-exposed lines of Sugita's interference patterns." In support of this contention, the Examiner's Answer points to Canon's FIG. 7A, 7B, and contends that "the line width of the pattern in figure 7B) is less than the linewidth of the line ... formed after the first interference exposure (linewidth of line in figure 7A).

Applicant respectfully disagrees. According to Canon:

> "When the projection exposure process for defining the exposure pattern of Figure 7A is performed, after dual-beam interference exposure process of Figure 5 without development process, superposedly to the same region of the same resist, the total exposure amount distribution of this resist is such as shown in the graph at the bottom of Figure 7B." *See Canon*, para. [0071] (emphasis added).

Thus, the line in FIG. 7A is defined using a projection exposure process, not an interference exposure process as contended by the examiner. Indeed, the exposure distribution shown in FIG. 7B is achieved only after a dual-beam interference exposure process. Accordingly, the smallest linewidth shown in Canon remains the linewidth achieved using an interference exposure process.

Further, please note that FIGS. 7A, 7B are entirely consistent with applicant's contention that the exposure of an unexposed line in Canon's interference pattern using a second exposure process will be ineffective to create a printable feature. In this regard, FIG. 7B shows the complete exposure of a line that is not exposed by an interference exposure process. Attention is directed to the region immediately to the right of the line that prints in FIG. 7B. As shown, this region is unexposed by interference lithography but exposed by projection lithography. However, this region is indistinguishable from the other regions that are not exposed by either interference lithography or projection lithography in the top portion of FIG. 7B. The complete exposure of an unexposed line is thus ineffective to create a printable feature.

At page 7, last full sentence, the Examiner's Answer contends that "Appellant is arguing embodiments such as figures 11A through 11D, and figures 9A, and 9B that are not relied upon by the Examiner."

Applicant respectfully disagrees and submits that these figures are relied upon by the Examiner both in the previous rejections and in the present Examiner's Answer.

As for FIGS. 11A-11D, the previous rejections and the present Examiner's answer contend that "Sugita, in [0105], discloses that the second linewidth is less than that of the first line width (claims 10 and 11)." *See Examiner's action*, page 3, para. 2; *Office action mailed Nov. 30, 2006*, page 2, para. 2.. *See also Office action mailed July 19, 2006*, page 2, para. 2. For the sake of convenience, para. [0105] is now reproduced:

> "Upper half of Figure 11C shows exposure amount distribution (exposure pattern) resulting from accumulation or superposition of exposure pattern of Figure 11A and exposure pattern of Figure 11B, in this embodiment. Lower half of Figure 11C shows a pattern which can be defined as a result of development process made to this exposure pattern. This embodiment uses a wafer resist having an exposure threshold larger than 1 and smaller than 2. For this reason, only the portion with exposure amount larger than 1 appears as a pattern as a result of development process. The shape and size of the pattern shown in the lower half of Figure 11C correspond to the shape and size of the gate pattern of Figure 10, respectively. It is seen therefore that, in accordance with the exposure method of this embodiment of the present invention, a circuit pattern with fine linewidth such as 0.1 micron, for example, can be produced by a projection exposure apparatus having an illumination optical system with which partially coherent illumination and coherent illumination can be performed selectively." *See Canon*, para. [0105] (emphasis added).

Accordingly, the previous rejections and the present Examiner's answer are both based on the disclosure of FIGS. 11A-11D.

As for FIGS. 9A and 9B, the previous rejections and the present Examiner's answer contend that "Sugita, in [0073], and [0105], discloses that the second linewidth can be less than that of the first line width." *See Examiner's action*, page 4, para. 4; *Office action mailed Nov. 30, 2006*, page 3, para. 4.. For the sake of convenience, para. [0073] is now reproduced:

> "The same concept applies also to a case where a linewidth three times larger than the exposure pattern of Figure 5 is to be produced, as illustrated in Figures 9A and 9B. For an exposure pattern of a linewidth four times larger or more, basically from the combination of exposure

> pattern with double linewidth and exposure pattern with triple linewidth, the linewidth of finally produced lithographic pattern is apparent. Any lithographic pattern that can be accomplished through projection exposure can be produced in this embodiment." *See Canon*, para. [0073] (emphasis added).

Accordingly, the previous rejections and the present Examiner's answer are both based on the disclosure of FIGS. 9A, 9B.

Since the portions cited to in the rejections are apparently not relied upon, the Examiner's Answer appears to be contending that the bases for the rejection set forth in the prior Office actions and in the present Examiner's Answer are improper. Applicant does not disagree with this contention.

At page 8, line 1-2, the Examiner's Answer contends that Applicant is arguing a limitation not recited in claim 10 and that "claim 10 does not recite that the second width is that of the non-exposed line. Claim 10 recites a first width of a non-exposed line, and a second width of at least one line exposed to radiation."

Applicant respectfully disagrees. In redacted form, claim 10 recites:

-"forming an interference pattern of non-exposed lines and exposed spaces,"

-"the [non-exposed] lines having a first width,"

-"exposing a portion of at least one [non-exposed] line to radiation to form features with a second width," and

-"the second width [is] less than the first width."

Thus, the recited second width is less than the width of the non-exposed lines of the recited interference pattern. Applicant is thus arguing limitations recited in claim 10. *See Appeal Brief filed May 29, 2007*; page 6, line 1-4 (arguing that none of the features in Canon have a width that is less than the width of the non-exposed lines of Canon's interference patterns).

At page 8, line 8-10, the Examiner's Answer contends that Canon in paras. [0071], [0073], [0074] discloses "a first linewidth that is larger than a second linewidth, and that the exposure distribution is adjusted such that a minimum linewidth (second width) can be produced."

While applicant does not disagree with these contentions as stated, please note that the first linewidth described in these paragraphs is a projection exposure linewidth while the second linewidth is the interference exposure linewidth. *See, e.g., Applicant's response to the contentions raised at page 6, line 15-page 7, line 2 of the Examiner's Answer above.* As discussed above, the "minimum linewidth [corresponds] to the resolution of dual-beam interference exposure (i.e., pattern of Figure 7B)." *See Canon*, para. [0074]. Thus, Canon fails to describe or suggest forming features with a second width that is less than a first width of non-exposed lines of an interference pattern, as recited in claim 10.

At page 8, line 16-page 9, line 2, the Examiner's Answer contends that the rejection of claim 25 is proper since Brueck, col. 2, line 46-52 and col. 6, line 34-36, and col. 8, line 52-58:

> "discloses that the non exposed areas (non exposed lines) [are] subjected to a second exposure and that the first exposure pattern (grating) has a period of 1 μm which corresponds to a line width of 0.5 μ, and that the final pattern of the line-space pattern has a linewidth of 100nm i.e., 0.1 μ. Therefore the second exposure process performed does trim the linewidth of the features (non exposed lines) from the first exposure i.e., trims the width from 0.5 μm to 0.1 μm."

Applicant respectfully disagrees on several different basis. In the interest of brevity, the cited sections are now reproduced.

The first cited section is a definition of "extreme submicron range."

> "'Extreme submicron range' means distances of the order of 0.1 .mu.m or 100 nm or less between lines.) Interferometric lithography may be combined with conventional lithography for the production of extreme submicrometer structures and the flexible interconnect technology necessary to produce useful structures." *See Brueck*, col. 2, line 46-52.

The second cited section discusses how lines in the grating pattern shown in FIG. 16 can be cut to produce the end result pattern shown in FIG. 19.

> "The end result pattern shown in FIG. 19 is produced by first exposing a 1-μm pitch grating over the entire area of the photoresist to produce the exposed photoresist image pattern shown in FIG. 167." *See Brueck*, col. 6, line 33-36.

The third cited section is step b) in claim 10.

> "b) exposing a second defined area containing the top edge of the first defined area with a second interference pattern of period p2 equal to twice p1 and with lines of constant exposure parallel to those of the first interference pattern, said second interference pattern being positioned relative to the first interference pattern such that every other unexposed region of the first exposure pattern within the second defined area is exposed." *See Brueck*, col. 6, line 33-36.

For purposes of this appeal, suffice it to say that none of the cited sections describe or suggest using a second lithography process to trim and narrow a width of at least some of the non-exposed lines of an interference pattern, as recited in claim 25. The first cited section is a definition.

The second cited section (discussing FIGS. 16-19) shows the cutting of lines of an interference pattern. Applicant respectfully submits that cutting the lines of an interference pattern does not trim and narrow their width.

The third cited section describes dual interference patterns, where the second interference pattern exposes every other unexposed region of the first exposure pattern. Applicant respectfully submits that exposing an unexposed region does not trim and narrow the width of the unexposed region.

At page 9, line 6, the Examiner's Answer contends that "Brueck is not relied upon for [its] cross grating patterns." At **page 9, line 10-13**, the Examiner's Answer contends that "Brueck, in col. 2, lines 43-46, discloses that the two dimensional pattern can be either interconnected or unconnected straight lines spaced apart from each other (line and space patterns)." (emphasis added).

For the sake of convenience, Brueck col. 2, line 38-46 is now reproduced:

> "The present invention provides complex, two-dimensional patterns in integrated circuits through the use of multiple grating exposures on the same or different photoresist layers and the use of complex amplitude and phase masks in one or both of the beams of illuminating coherent radiation. ('Complex, two-dimensional patterns' as used herein means a

> pattern of multiple, interconnected and/or unconnected straight or curved lines or bodies spaced apart from each other." *See Brueck,* col. 2, line 38-46 (emphasis added).

Complex, two-dimensional patterns that use multiple grating exposures are discussed in more detail elsewhere in Brueck. For example, according to Brueck

> "[i]n accordance with the invention the complex interference pattern produced on the photoresist layer or layers is varied by (a) rotating the wafer, (b) translating the wafer, (c) both rotating and translating the wafer, (d) changing the angle A, (e) varying the number of exposures, (f) varying the optical intensity, (g) using a phase/amplitude mask in one or both illuminating beams of coherent radiation, or (h) employing any combination of (a)-(g). Further flexibility is offered by a combination of any of (a)-(g) with conventional or imaging lithography techniques as are well known." *See Brueck,* col. 4, line 20-30.

Accordingly, reference by the rejection to characteristics of Brueck's "complex, two-dimensional patterns" is believed to inherently encompass characteristics of Brueck's cross-grating patterns. Indeed, the very characteristics relied upon in both the rejection and the Examiner's Answer appear to require crossed grating patterns. For example, the "interconnected" straight lines shown in Brueck's FIGS. 8-14 were clearly formed with crossed grating patterns. *See Brueck,* Table 1 (discussing the angles at which the grating patterns were crossed).

Further, to the extent that the current rejection is based on complex, two-dimensional patterns formed using "a combination of any of (a)-(g) with conventional or imaging lithography techniques," Brueck describes that the *entire width* of a non-exposed line can be exposed using conventional lithography techniques. For example, the entire width of the non-exposed lines of the interference pattern of FIG. 16 can be exposed using the sequential exposures of FIGS. 17 and 18. *See Brueck*, col. 6, line 36-41. This yields the pattern of FIG. 19. *See Brueck*, col. 6, line 42-45.

Such an exposure of the entire width of a non-exposed line neither describes nor suggests the use of a second lithography process to trim and narrow a width of non-exposed lines by exposing portions of the non-exposed lines using a second exposure having a second pitch, as recited in claim 25. Rather, exposure of the entire width of a line removes the entire line.

At page 9, line 13-15, the Examiner's Answer contends that Canon "is not limited to a multiplex exposure embodiment" and refers to page 6, line 7-13 of the Examiner's Answer, which were discussed above.

Applicant respectfully disagrees. As discussed above, an exposure process is not an exposure level. Moreover, two exposure processes are multiple in number.

At page 9, line 16-19, the Examiner's Answer contends that the motivation to combine allegedly disclosed in para. 4 of the rejection addresses Applicant's argument that the combination of Brueck and Sugita would lead those of ordinary skill to the recited subject matter.

Applicant respectfully disagrees. As discussed, e.g., at page 12-13 of the appeal brief, even if Brueck and Sugita were combined, one of ordinary skill would not arrive at the recited subject matter. In particular,

> "Canon uses the accumulation/superimposition of dosages from multiple exposures to demarcate printing from non-printing regions. However, the rejection is silent as to the relationship between the dosages delivered by Brueck's crossed interferometric exposures and the exposure thresholds relied upon by Canon. For example, an attempt to trim a non-exposed region (i.e., a "0" region) using a "1" exposure will still leave that region below Canon's threshold exposure level (i.e., at an exposure level "1").

> Since Canon's "1" and "0" exposure levels are both below the threshold exposure level, they will both be printed or not printed together." *See Appeal Brief*, page 12, first paragraph.

At page 10, line 1-10, the Examiner's Answer contends that Applicant's appeal is somehow deficient for arguing that the rejection is silent as to the relationship between the dosages delivered by Brueck's crossed interferometric exposures and the exposure thresholds relied upon by Canon because "claim 25 does not limits any of the exposure processes."

Applicant respectfully disagrees. Applicant is not arguing limitations that are not present in claim 25. Rather, Applicant is questioning the fundamental contention that Brueck and Canon can be combined to arrive at the recited subject matter.

In particular, claim 25 is rejected under 35 U.S.C. § 103(a), which requires that the recited subject matter as a whole would have been obvious to a person having ordinary skill. In the present case, the rejection has not set forth any basis for believing that Brueck and Canon can, in fact, be combined to arrive at the recited subject, much less that it would be obvious for one of ordinary skill to have done so.

Applicant thus repeats the contention that a proper combination of Brueck and Canon requires some explanation of how Brueck's and Canon's technologies can be combined to arrive at the recited subject matter.

At page 10, line 1-10, the Examiner's Answer contends that page 8, line 12-page 9, line 15 of the Examiner's Answer describes the trimming of the linewidths of unexposed lines of interference patterns.

Applicant respectfully disagrees for at least the reasons discussed above in response to those sections of the Examiner's Answer.

At page 11, line 1-13, the Examiner's Answer contends that page 9, line 3-19 of the Examiner's Answer describes the trimming of the linewidths of unexposed lines of interference patterns.

Applicant respectfully disagrees for at least the reasons discussed above in response to those sections of the Examiner's Answer.

At page 11, line 4-16 and page 12, line 1-5, the Examiner's Answer contends that Brueck's and Sugita's description of alignment processes inherently describe or suggest an alignment apparatus that is to align selected areas radiated by a second apparatus with an interference pattern radiated by a first apparatus to trim and narrow the width of unexposed lines in an interference pattern.

Applicant respectfully disagrees. Alignment can be performed at a number of different resolutions. For example, the space shuttle must be aligned with a space station before docking. Accordingly, every alignment process does not inherently involve alignment that suffices to trim and narrow the width of unexposed lines in an interference pattern.

At page 11, line 17-page 12, line 1, the Examiner's Answer again contends that Applicant is arguing embodiments in Brueck that were not relied on in the rejections.

As discussed above, applicant respectfully disagrees and instead submits that the very characteristics relied upon in both the rejection and the Examiner's Answer appear to require crossed grating patterns.

For these reasons, and the reasons stated in the Appeal Brief, Applicant submits that the final rejection should be reversed.

Please apply any charges or credits to Deposit Account No. 06-1050.

Respectfully submitted,

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